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Examining the Effects of Covered Landfills on Gas Emissions in Parc Baldwin, Montreal

Research Article

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Abstract

Background: Within recent years, parks built on top of former landfills have come under scrutiny for their effectiveness at mitigating the effects of the landfill underneath. The purpose of this study is to identify the biogas emissions of converted landfills nearly a century after landfill closure.

Methods: Soil and air emissions for methane and carbon dioxide were collected at 112 sites within the North and South portions of Parc Baldwin in Montreal, Quebec, as well as the presumed boundaries of the former landfill.

Results: Overall, it was found that South Baldwin and the immediate area (previously a landfill) had a higher mean average methane concentration, as well as a greater number of sites with methane present than North Baldwin. Particular raised areas in South Baldwin showed anomalously high carbon dioxide concentrations. There was a large degree of heterogeneity between emissions at different sites.

Limitations: The Eagle 2 machine is limited to measuring only up to 5,000 ppm or 0.5% volume. Another difficulty with the variation in collection of the data is the differences in collection dates.

Conclusions: Ultimately, while South Baldwin did have higher CO2 and methane emissions compared to its counterpart, it is inconclusive whether or not this phenomenon is related to the landfill or other factors. Gas concentrations were significantly below the lower explosive limit in both parks.

Introduction

Throughout the 20th century, cities all over the world converted former landfills into parks and residential areas. Many dangers are associated with landfills, including toxicity, dangerous wastes, carcinogenic compounds, and the release of methane and carbon dioxide emissions. (1) Covering landfills was thought to decrease the dangers associated with these exposed areas, however, it is not a perfect solution. (2) Despite conversion, the continued release of methane and carbon dioxide contribute to potential local health problems, risks of explosions, and global climate change. In Montreal alone, there are 62 former landfills and quarries that have been converted to parks or residential areas. (3)

In 1994, the city of Montreal published the results of a four-year study investigating the extent of biogas emissions from multiple converted landfills across the city. The objective of the study was to determine the boundaries and impacts of former landfill sites using methane emissions as a proxy. From this study, one particular park of interest was Parc Baldwin South. Though the landfill under Parc Baldwin south ceased operation in 1924, residents near the park complained about high biogas emissions. Preliminary tests in 1991 showed all locations of Parc Baldwin South to have methane emission levels below the lower explosive limit (LEL) of 50,000 ppm. The survey in 1992 showed no significant changes in methane level from the 1991 results, with the exception of the apartment building at 3480 Fullum where methane concentrations exceeded the LEL. When repeated in 1993 and 1994, the emissions readings showed the same results as the 1992 survey. From these results, the 1994 study concluded that biogas surveillance of the houses along Fullum is crucial. In addition, the study claimed that more research is necessary in order to determine the extent of the biogas in the park itself. (4)

In 2013, the release of data illustrating former landfills through Montreal, as well as the closure of a community garden in South Baldwin due to heavy metal contamination, re-sparked concerns regarding converted landfills. The city of Montreal responded to these concerns in 2016 by conducting additional surveys for methane concentrations in converted landfills through the main districts of Montreal. A major area of concern was the Mont-Royal/Plateau district in which Parc Baldwin is located. In this district, 16 sites were analyzed. Overall, the study concluded that the average methane emissions in the area were 7 ppm with the highest recording at 12 ppm. This contradicts the previous 1994 study in which methane levels in the area exceeded the lower explosive limit of 50,000 ppm. The study has concluded that the Mount-Royal/Plateau district has negligible amounts of methane and the city of Montreal would not be focusing resources towards a threat deemed insignificant.

Due to persistent complaints from residents concerning high methane levels near the Parc Baldwin area, it is unclear how accurate the prior studies were at analyzing biogas emissions. We sought to determine the accuracy of the 1994 and 2016 results produced by the city of Montreal, and analyze the impact a covered landfill can have almost a century after its closure. For our study, gas emissions from both a covered landfill and a non-landfill greenspace were compared at Parc Baldwin North and Parc Baldwin South in the Montreal downtown area. North Baldwin served as the control since it does not cover a landfill, whereas South Baldwin and the surrounding area were observed for anomalous emissions.

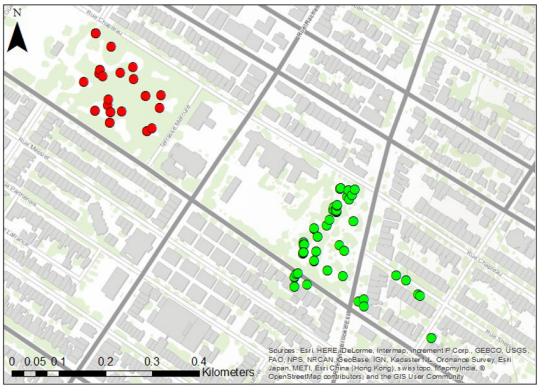
Comparing the gas emissions from these two parks can further facilitate categorizing and identifying key emissions that could indicate the presence of a landfill under a park. The results can also help determine if the construction of parks on covered landfills has an effect on the emissions from the landfill underneath, and if they could possibly reach problematic levels. In addition, the emissions data could potentially be used to create predictive models in order to identify unknown previous landfills covered by parks, as well as be used to identify the boundaries of landfills, if not previously known. Lastly, this study could be used to corroborate or dispute the 1994 and 2016 studies, and help provide a more extensive base for future studies into landfill emissions. It is expected that overall biogas emissions will be higher at Parc Baldwin South compared to Parc Baldwin North due to the presence of the landfill. We expect to see this trend in areas surrounding Baldwin South as well, given that the former landfill extended beyond the park into the surrounding residential areas.

Methods

Emissions data was collected using two machines, the Eagle 2, and the Triple Plus+. Both machines analyze CO2 emissions with differing accuracy; the Eagle 2 detected CO2 up to 10,000 ppm, whereas the Triple Plus+ could measure CO2 up to 50,000 ppm. Only the Eagle 2 was equipped with a methane sensor, which was capable of measuring up to 50,000 ppm CH4. Data was collected over 4 different days between October and November. Care was taken to collect data on days with relatively low wind speeds, to avoid dispersal of any gas emissions in the air. Overall, 112 data points were collected from the four days, consisting of 29 samples from Parc Baldwin North and 83 samples from Parc Baldwin South (including several sites south of Sherbrooke). A more extensive breakdown of the data collection can be seen in Table 1. For the first two data collection days (October 31 and November 7), only the Eagle 2 was used. For the third and fourth data collection days (November 14 and 16), the Triple Plus was also used, and the machines were run in tandem in order to better assess the emissions in both parks. The locations in which samples were taken from Parc Baldwin South and Parc Baldwin North can be seen in Figure 1.

A general assumption was made that Parc Baldwin North was representative of standard background emissions and thus each machine was calibrated to the air in the center of the park. This was done in order to show any relative changes in methane and carbon dioxide when comparing the conditions in Parc Baldwin North and Parc Baldwin South. For the testing of soil emissions, either the Eagle 2 or Triple Plus (or both, in turn) was connected to a metal soil probe using plastic tubing. The probe was then inserted into the ground to a depth of approximately 0.3-0.6m, depending on the soil hardness. Air emissions data was collected in a similar fashion: the tubing for the respective machine was left open (not connected to the soil probe) and held directly over the ground at the site, at a height of approximately 1-2 cm. For both soil and air measurements, adequate time was given for the machine to stabilize before any values were recorded, which was found to be roughly 30 seconds.

Both machines were equipped with alarms that would sound when CO2 concentrations exceeded the threshold of the sensors. The Eagle 2 would sound the alarm at 5,000 ppm, whereas the Triple Plus+ could tolerate concentrations of up to 50,000 ppm. As a result of this, the Triple Plus+ was used first (on days where it was available) to determine if the CO2 emissions exceeded the limits for the Eagle 2 (and therefore no methane or additional CO2 measurements could be collected).



Date of Data Collection	Eagle 2	Triple Plus+	Wind Speed (km/hr)	# of North Baldwin Sites	# of South Baldwin Sites	# of South Sherbrooke Sites	Total
October 31	Yes	No	14	6	9	1	16
November 7	Yes	No	13	3	15	1	19
November 14	Yes	Yes	14	6	25	7	38
November 16	Yes	Yes	6	14	23	2	39

Fig. 1. Location of samples taken from North and South Baldwin over all four days of sampling. North Baldwin sites are darker in colour South Baldwin sites are lighter in colour.
Table 1. Detail about data collection at Parc Baldwin North and South.

Results

As seen in Figure 2A, the correlation between the Triple + and Eagle 2 machines have an R2 value of 0.945 when recording carbon dioxide, indicating that the two machines are quite consistent.

When looking at only soil samples, the correlation between methane and carbon dioxide emissions from the Eagle 2 is weak with a R2 value of 0.005 (Figure 2C), showing that the presence of carbon dioxide emissions are not indicative of the presence of methane emissions for the soil.Comparing methane and carbon emissions for only the air samples from the Eagle 2 shows a weak correlation with a R2 value of 0.016 (Figure 2D). This is

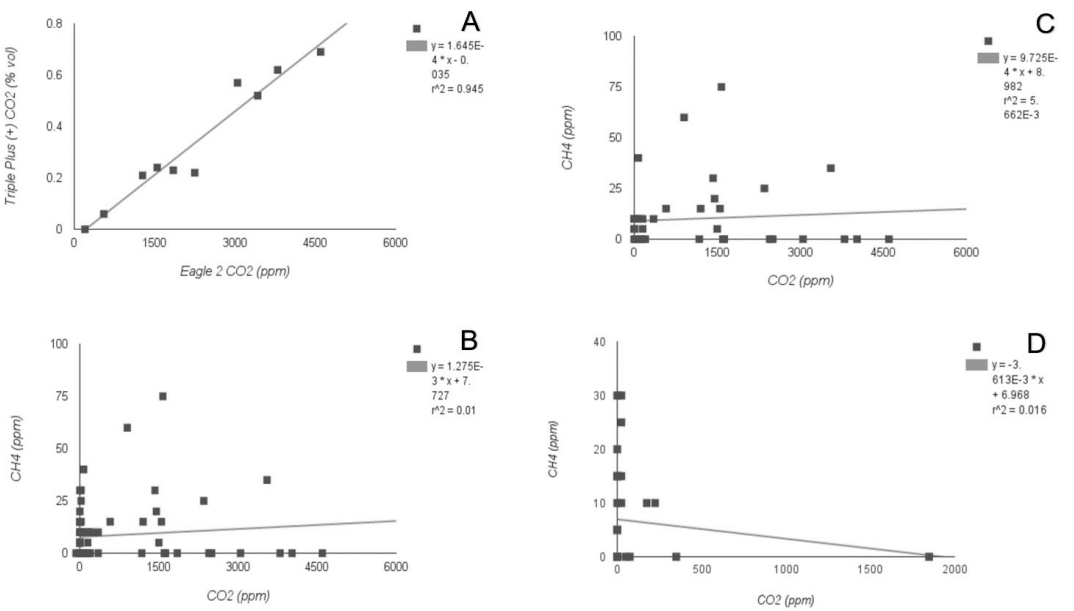


Fig. 2 (A) Correlation Between Triple+ and Eagle 2 Carbon Dioxide Measurements. (B) Correlation Between Methane and Carbon Dioxide Measurements in the Soil and Air using the Eagle 2. (C) Correlation Between Methane and Carbon Dioxide Measurements in the Soil using the Eagle 2. (D) Correlation Between Methane and Carbon Dioxide Measurements in the Air using the Eagle 2.

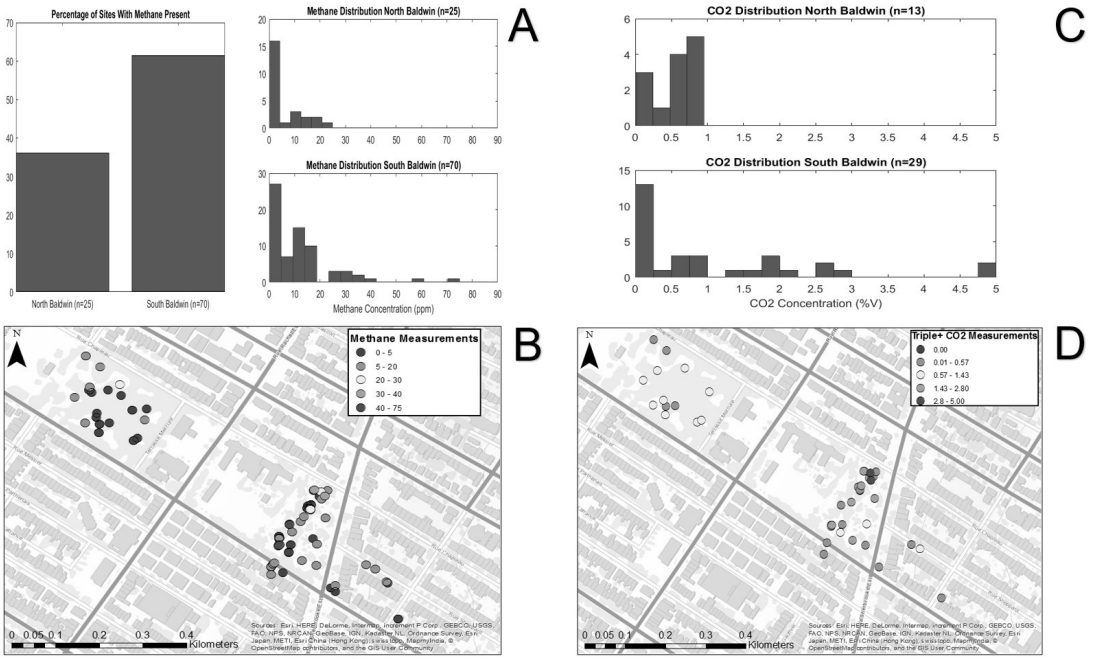


Fig. 3 (A) Statistical distribution of CH4 presence in North and South Baldwin sites, statistical distribution of methane in North Baldwin, statistical distribution of CH4 in South Baldwin. (B) Spatial distribution of CH4 emissions (ppm). (C) Statistical distribution of CO2 in North Baldwin and South Baldwin. (D) Spatial distribution of CO2 emissions (% volume).

consistent with the previously mentioned lack of correlation between soil measurements from the Eagle 2, showing that carbon dioxide emissions are not related to the presence of methane emissions for the air as well.

Overall, Baldwin South had a higher number of sites with methane present than Baldwin North. The highest concentration of methane in North Baldwin was 25 ppm while the highest concentration in South Baldwin was 75 ppm. Figure 3A shows that there were more sites with higher methane concentrations in South Baldwin as compared to North Baldwin, but with a higher standard deviation for South. The spatial distribution of these sites can be seen in Figure 3B. As with methane emissions, Baldwin South had a higher standard deviation for carbon dioxide (Figure 3C). Carbon dioxide concentrations were higher in South Baldwin as well: the highest concentration of CO2 present in South Baldwin was >5% V, compared to 1.43% V in North Baldwin. The spatial distribution of these sites can be seen in Figure 3D.

An interesting trend was observed in South Baldwin, where elevated sections of the park, deemed "lumps", showed extremely high CO2 concentrations. They are clearly visible in Figure 3B as the clusters of darker points in South Baldwin. When CO2 measurements are sorted and grouped, this relationship becomes clearer, as seen in Figure 4.

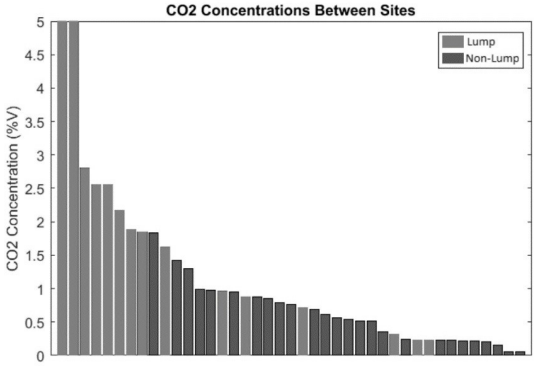


Fig. 4 Sorted Carbon Dioxide emissions grouped by position on or off of "lumps".

Discussion

Comparison to 1994 and 2016 Study

Similar to the 1994 study, our results show negligible amounts of methane in Parc Baldwin itself with respect to the LEL. Furthermore, while the methane emissions near the 3480 Fullum house were higher than ambient levels, they did not come remotely near the LEL, possibly due to successful remediation. Although we did find areas with relatively high methane emissions, the values observed were still extremely low (<0.2% of the LEL). Regarding the 2016 study, our results were far less similar. For the Mont-Royal/Plateau district (where Baldwin Park is located), the city of Montreal found an average methane concentration of 7 ppm, whereas our results suggested an average of 15 ppm. The city also reported that the highest methane concentration was only 12 ppm, whereas the highest concentration that we detected was 75 ppm. While the results of the study did not find methane levels above the LEL, the study did show higher levels of methane than the data recorded in the 2016 study. Ultimately, while we did find higher concentrations of methane than the City of Montreal detected in their 2016 study, the magnitude of emissions is minuscule with respect to the LEL.

Comparing North and South Emissions

Both carbon dioxide and methane concentrations are higher in Parc Baldwin South as compared to North Baldwin, although there is a higher standard deviation in concentrations for South Baldwin. There appears to be no correlation between the presence of CO2 and methane in air and soil samples across both parks. While these overall higher emissions in South Baldwin are potentially due to the presence of the landfill underneath, there are still many unknown factors that would need to be tested in order to draw a more certain conclusion.

Lump Sites

One of the more interesting findings during field data collection was the presence of at least three "lumps" in Parc Baldwin South. The lumps were characterized as being slightly elevated above the surrounding ground and devoid of trees. They ranged in size from a couple meters across to over 10 meters in length (the Eastern Lump). Measurements taken on these lumps showed drastically higher concentrations of methane and carbon dioxide

than the immediate surrounding area off the lump. The lumps consistently had soil CO2 concentrations that were greater than 5,000 ppm, which rendered the Eagle 2 unable to measure soil methane levels. However, air measurements made with the Eagle directly over the ground of the lumps showed higher than normal methane concentrations, sometimes as high as 60 ppm. It was interesting to note that moving off or away from the lump resulted in CO2 and methane levels dropping immediately back down to more ambient levels, even if the distance moved was less than a meter off the lump.

Additionally, the soils group found that the soil type for the lumps was different than for the rest of the park. Clay soil was consistently found at sites near the lumps but not on them, while the soil for the lumps themselves was more broken and less dense. This difference in soil type could possibly explain why the lumps had much higher emissions that the surrounding areas, as the clay soil is less permeable and would block emissions from off the lumps. The less dense soil on the lumps would allow for gas emissions below to more easily escape and cause higher measurements of CO2 and methane emissions at those lump sites.

Connection to Related Study Groups

When analyzing temperature data from the parks, the thermal signature results from the thermal group are not consistent with the emissions results, with the exception of potential elevated temperatures on the eastern lump. However, it is ambiguous whether this is due to the presence of a landfill or other factors such as sunlight exposure, depth of sensor placement, or density of the soil surrounding the sensor when placed into the auger hole. Looking at the results from the soil group regarding the soil chemistry of the park, the soil group has concluded that there is no concrete evidence that the presence of a landfill contributes to higher heavy metal composition. The copper, chromium, and iron samples in the soil were determined to be insignificant and only one site had a large amount of heavy metals. This anomalous site could potentially be caused by the location's proximity to Sherbrooke. While the group was not able to concretely conclude that the presence of the landfill underneath South Baldwin led to increasing heavy metal concentrations, it is important to note that the soil group was unable to test the lump sites. This is important to take into consideration since lump sites are the areas which have the highest emission concentrations and could potentially have the largest concentration of heavy metals as well.

Using the emissions model created by the modelling group, the model has predicted that emissions drastically decline immediately after the closure of landfills, and plateau towards zero after approximately fifty years. Adapting this model to Parc Baldwin South, one can determine that the emissions should be almost zero today, as the landfill closed in 1924. This is consistent with the results of the study since the average methane observed in this area was 15 ppm.

Future Work

Future research on this topic will be able to determine the full effects of landfills on the emissions gas at Parc Baldwin. More analysis regarding the characteristics of lump sites would be necessary in order to determine their importance. These characteristics can include soil properties, which can facilitate this study in understanding if the emissions from these areas are due to soil composition or the presence of a landfill. In addition, having measurements that reach further depths in the ground could lead to more accurate depictions regarding the effects of the landfill. This is because deeper soil would not be affected by any external emissions, which would make the results more accurate. Additionally, historical information regarding the closure of the landfill, the composition of the landfill, and any remediation practices could help determine the cause of these emissions. Analysis of historical information could allow for more conclusive evidence linking the landfill to the emissions. Another important addition to this study would be using this information to create predictive models. These models can help determine the extent of the landfill and predict the boundaries for old landfills now covered by parks. Lastly, expanding this study to other landfill covered parks and not only focusing on Parc Baldwin could determine the extent that parks with landfills below have on biogas emissions.

Limitations

While the data in this study is significant, there are some important caveats to consider. One consideration to recognize is that the Eagle 2 machine is limited to measuring only up to 5,000 ppm or 0.5% volume. Therefore, any concentrations higher than this limit would set off an alarm and the machine would need to reset. This would prevent measuring carbon dioxide as well as methane on any sites with carbon dioxide higher than 5,000 ppm. This means that the Eagle 2 could not be used to measure methane or carbon dioxide on the lumps since these areas had higher than 0.5% volume and the Triple + machine was the sole measurement of carbon dioxide concentrations for the lump areas.

Another difficulty with the collection of the data is the differences in collection dates. The first consideration is the differences in the time of day. Measuring closer to peak rush hour may cause air emissions to be higher due to the high amounts of traffic, which could increase methane and carbon dioxide readings from the influx of combustion engines on the road. In addition, the weather conditions can affect the data. Days with rain could increase microbial decomposition and could increase the carbon dioxide readings on days after rain. Another weather consideration is the amount of wind. Despite the fact that the team attempted to go on days with low wind, even wind speeds of over 10 km/h could drastically decrease and disperse the low levels of methane in the air directly above the ground. Further, there is the change in seasons to consider. The dates where data was collected spanned from October to November, where the leaves were constantly falling from the trees and covering the ground. Therefore, later dates when the leaves were on the ground had higher overall carbon dioxide readings when compared to dates in which the leaves were still on the trees. This could be due to the decomposition of the leaves, as well as the leaves acting as a barrier above the ground that would prevent gas emissions from dispersing into the air.

Conclusion

The results from this study show that there are higher average methane and carbon dioxide concentrations for the South portion of Parc Baldwin as compared to North Baldwin. In addition, a larger percentage of sites in Parc Baldwin South had a presence of methane when compared to North Baldwin. However, it is important to note that South Baldwin had a larger standard deviation in methane concentrations when compared to North Baldwin. While the methane levels reported were all significantly below the lower explosive limit of 5% volume, methane was still present.
While there is evidence that landfill covered Parc South Baldwin has higher emissions compared to its control Parc North Baldwin, the data cannot conclusively determine if the emissions are due to the presence of a landfill or there is some other factor at play. These other factors could be its proximity to Sherbrooke, seasonal or weather factors, or soil composition. More studies and tests as well as access to historical information would be needed in order to confirm that the emissions were due to the landfill below the park.

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